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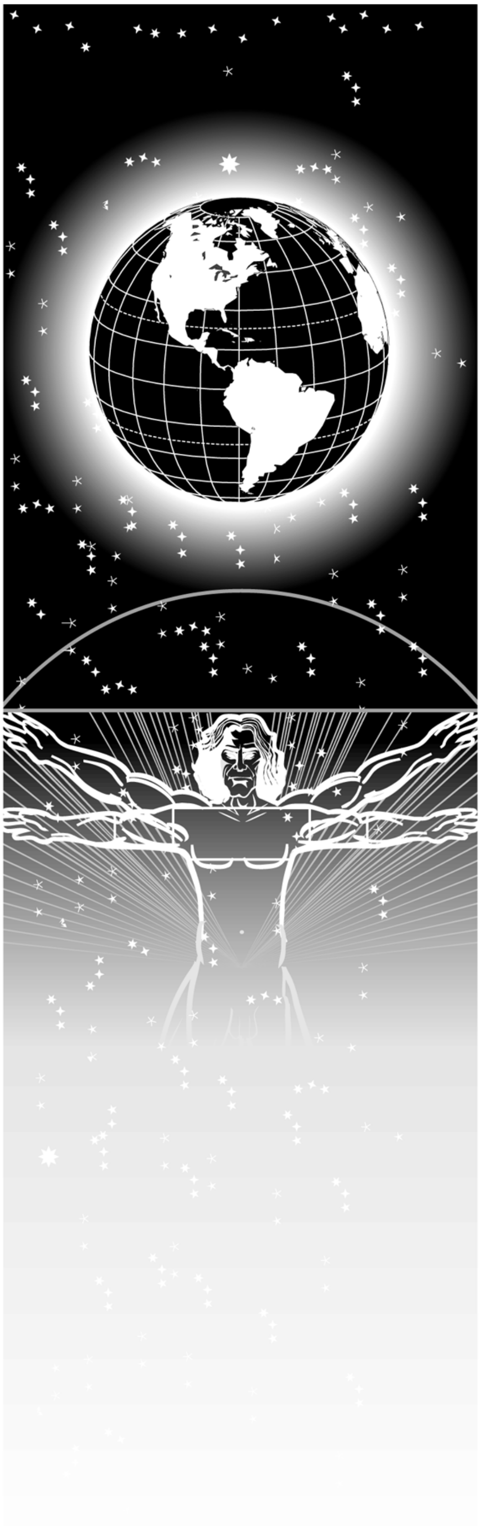

UNITED STATES AIR FORCE
AFIOH

Lead Free Frangible Ammunition Exposure at United States Air Force Small Arms Firing Ranges, 2005 - 2007

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14. ABSTRACT

Historically, lead has posed a significant safety, environmental, and health hazard at United States Air Force small-arms firing ranges. By 2004, USAF approved the use of lead free frangible (LFF) ammunition for training environments. Since changing to LFF, instructors at several facilities have reported eye and upper respiratory irritation. Over 500 air samples were collected to characterize instructor exposures to metals and irritant gases; all contaminant levels were found to be well below occupational exposure levels. The muzzle exhaust from M4 rifles firing lead and LFF ammunition was analyzed for metals, irritant gases and VOCs. Lead was found to be 600-1000 times higher in the firing of lead bullets; otherwise, no significant difference was noted in emissions between the two ammunition types. A screening questionnaire was distributed to range instructors using LFF or lead ammunition. Rates of health complaints were similar from both types of ammunition. Results suggest that the accumulation of contaminants due to poor airflow is responsible for the reported health effects and not unique hazards from the LFF ammunition.

15. SUBJECT TERMS

Frangible, Ammunition, CATM, Ranges, Health

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LEAD FREE FRANGIBLE AMMUNITION EXPOSURE AT UNITED STATES AIR FORCE SMALL ARMS FIRING RANGES, 2005-2007

PURPOSE

This report serves to summarize various projects the Air Force Institute for Operational Health (AFIOH) has performed related to health concerns expressed by Security Forces Combat Arms (CATM) instructors regarding exposure to contaminants generated during the discharge of lead free frangible ammunition. The projects took place from 2005 through 2007 and while work is ongoing in this area, the results contribute to our understanding of the exposures enough that reasonable, timely recommendations can be made. Generally, this report provides needed exposure data and recommendations to health risk assessors in the field, it identifies gaps in the assessment needing further work, and it gives recommendations to CATM personnel to mitigate the hazards as they are currently understood. It should serve to provide operators in the field to help mitigate the reported adverse health effects of respiratory tract irritation, eye irritation, sweet metallic taste, nausea and headaches.

INTRODUCTION

Historically, most small-arms firing-range health related problems stemmed from the presence of lead and lead compounds found in the bullets and priming mixtures. Increasingly stringent Federal and state environmental regulations caused the Air Force to develop new range designs that significantly reduce or eliminate the discharge of lead into the environment. Open ranges with earth backstops or impact ranges (no backstop) began to be replaced in the mid-1990s. The newer ranges restrict the path of the bullet and contain all bullets within the confines of the range. The ranges are partially or fully contained using walls and commercial bullet traps. The unforeseen effect of solving the environmental problems was the creation of a range that may have poor airflow compared to the older open ranges. This resulted in the increased risk of elevated airborne lead levels to shooters and CATM instructors.

To eliminate the lead hazard, the Air Force began investigating the use of lead free frangible ammunition for small arms training for the M-9, M-16, and M-4 weapons. The frangible rounds were considered non-toxic because lead was removed from the bullet and the primer. Additionally, the frangible rounds had little to no ricochet hazard significantly reducing the safety hazard distance. Frangible bullets consist of compacted metal powder formed into a bullet that has sufficient strength to maintain its integrity during firing while fragmenting on impact with a solid object. Initially, frangible ammunition was purchased from Olin Winchester and the bullet consisted of a blend of powdered copper and tungsten with a nylon binder. The Air Force is currently using a frangible bullet consisting of powder copper metal and nylon binder manufactured by Federal Cartridge Company.

As early as 2000, ranges began using frangible ammunition but the transition across the Air Force didn't begin until 2004. Some ranges continue to use lead ball rounds. AFIOH performed an initial evaluation of exposure to frangible ammunition at Randolph AFB in October 2000[7] and Columbus AFB in December 2000[8]. Metals analysis (copper, lead, nickel, tungsten and zinc) was performed at both bases and toxic gases (ammonia and hydrogen cyanide) was conducted at Columbus AFB. Air monitoring results showed all contaminant levels well below the Air Force Occupational Exposure Levels (OELs). However, it was noted at Columbus that personnel had reported eye and nasal irritation. The ventilation system at Columbus was also determined to be inadequate.

In 2005, instructors at several Air Combat Command (ACC) ranges using frangible ammunition began reporting the occurrence of eye and upper respiratory irritation. HQ ACC/SGPB requested that AFIOH evaluate CATM instructor's exposure to contaminants resulting from the use of frangible ammunition. In response, AFIOH performed air sampling and ventilation assessments at five ACC CATM ranges. This air sampling effort still left uncertainties as to the relationship between the contaminants produced by firing the frangible ammunition and the reported health effects so further studies were performed. Therefore, additional studies were performed to include an epidemiological questionnaire surveying all CATM instructors within ACC about reported complaints and a chamber study was conducted where the contents of rifle exhaust was captured and analyzed. These are the projects that are summarized in this report.

During the discharge of a weapon, there is a complex mixture of contaminants (particulates and gases) that could be expelled into the nearby air. The combustion of the propellant and priming mixtures will result in the generation of many combustion byproducts in addition to unburned propellant ingredients. Copper and trace metals may be released as a fume or a dust from the heat or mechanical action of firing. AFIOH used previous survey reports performed by the Air Force[7,8], the Army[9], and known combustion by-products of ingredients listed on the frangible bullet MSDS, see appendix E.

The Air Force policy governing OELs, AFOSH Standard 48-8, *Controlling Exposures to Hazardous Materials*, requires the use the most stringent standard from the Occupational Health and Safety Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH) or an Air Force specific standard. Unfortunately, there are many compounds that do not have established OELs and this makes it difficult to ascertain if a certain concentration poses a health risk to personnel. OEL's also do not account for complex mixtures such as that present in the exhaust materials of a weapon. Copper does have an established OEL but it is complicated by the fact that there is an OEL for copper as fume and a separate OEL for copper as a dust. It is suspected that both forms of copper are present on the range but it has not been determined how much of the copper is a fume and how much is a dust. Traditional sampling methods do not separate dust from fume making it difficult to determine which standard is most applicable. The OEL for copper is 1 mg/m^3 as a dust or 0.1 mg/m^3 as a fume. These levels are set to protect workers from respiratory irritation and metal fume fever.

Air movement is necessary to remove airborne contaminants generated by weapons firing. Outdoor ranges rely on natural ventilation, i.e. wind, while indoor ranges require the use of mechanical ventilation to push contaminants down range away from personnel. Most range ventilation requirements are based on a technical report published by NIOSH back in 1976. Many ranges at the time did not adequately control lead exposures. NIOSH conducted a study with American Filter Company to determine ventilation rates for indoor firing ranges. They found that a minimum ventilation rate of 50 fpm at the firing line is needed to control exposures to lead and combustion by-products and 75 fpm being the optimal ventilation rate. NIOSH also determined that ventilation rate alone is not sufficient to control exposures. The airflow must be balanced and evenly distributed (laminar flow) to ensure contaminants are removed from personnel's breathing zone. The Air Force has incorporated these guidelines into its range design criteria found in Civil Engineering's Engineering Technical Letter: *Small Arms Range Design and Construction*. It requires laminar airflow with a ventilation rate of 75 fpm at the firing line to control lead exposures.

In spite of the ETL ventilation guidelines, poor airflow continues to plague Air Force firing ranges. Most AF ranges are considered outdoor ranges and are not equipped with mechanical ventilation systems. Some indoor ranges, although they have mechanical ventilation systems, do not adequately control contaminant exposures due to poor design and/or lack of maintenance. Outdoor ranges usually rely on natural ventilation; however, the AF has adopted a fully contained range design which severely restricts natural ventilation airflows. This type of range configuration allows contaminants generated during the discharge of ammunition to accumulate within the breathing zone of range personnel.

Mechanical ventilation systems are not installed on fully contained outdoor ranges for several reasons. First, fully contained ranges are classified as outdoor ranges and it was assumed that natural ventilation would be sufficient to control any exposures. Second, many ranges switched to the "non-toxic" frangible ammunition and it was thought that controls would not be needed due to reduced lead exposure. Third, ventilation systems are avoided because they add significant cost to construction, and there are expensive to operate due to recurring maintenance and energy costs. Fourth, they may not help much because they are exposed to prevailing weather conditions potentially negating the ability of the system to remove contaminants. Some outdoor ranges have installed some form of mechanical ventilation but still are at risk of experiencing unacceptable exposures due to poor design and/or variability of weather conditions.

AIR MONITORING

Methods

Measurements of contaminants were made at five ACC CATM ranges. Four ranges used lead free frangible ammunition and one range used lead ball rounds, see table 1. Both personal breathing zone and area samples were collected. Personal samplers were placed on instructors working the firing line. Area samplers were placed on the red line at the shooters prone position. Standard National Institute of Occupational Safety and Health (NIOSH) methods were used for the collection and analysis of air contaminants. Detailed method information can be found in each bases' individual report[2-6]. In addition to NIOSH methods, cascade impactors were used at Offutt AFB and Shaw AFB to examine the particle size distribution of copper released during the firing of frangible ammunition. Samples were collected using the Marple 290 personal cascade impactor with a flow rate of 2 liters per minute. The impactors had eight stages and the 50% cut points ranged from 0.52 – 21.3 microns. The impactors were positioned at the same location as the area samples.

In addition to air monitoring, a qualitative assessment was made of airflow within the firing range using American DJ Fogstorm 1700HD. A fog was released at the firing line and observed as it dissipated throughout the range. Airflow assessments were made at all of the ranges except Ellsworth AFB.

TABLE 1. Base and Ammunition Type

Base	Ammunition	Manufacturer
Barksdale AFB	Lead	Unknown
Ellsworth AFB	Frangible	Olin Winchester
Offutt AFB	Frangible	Federal Cartridge Company
Shaw AFB	Frangible	Federal Cartridge Company
Whiteman AFB	Frangible	Federal Cartridge Company

Results

Table 2 contains a summary of personal air monitoring results from the various bases. Area sample results were similar to the personal air sample results and can be found in appendix D. Three gaseous contaminants were detected: ammonia, hydrogen cyanide and phosgene. Ammonia was detected in 1 of 24 samples, hydrogen cyanide was detected in 4 of 24 samples and phosgene was detected in only 1 of 12 samples. The concentration of toxic gases was found to be less than 2 percent of their respective OELs.

For frangible ammunition, copper, lead and zinc were detected. All zinc samples were detected at concentrations less than one percent of the OEL. One area sample for lead had a concentration of 50 percent of the OEL while the remainder of the samples was well below the action level for lead. All samples had detectable levels of copper. At Whiteman AFB and Shaw AFB, the airborne concentrations of copper exceeded the copper fume OEL. No copper sample exceeded the copper dust OEL.

During the firing of lead ball rounds at Barksdale AFB, only a metals analysis was performed. Both copper and lead were detected. Copper concentrations were less than 40 percent of the fume OEL. Airborne concentrations of lead exceeded the OEL on one of the two sampling days.

TABLE 2. Summary of Personal Air Monitoring Results

		Barksdale AFB (2 days)			Ellsworth AFB (1 day)			Offutt AFB (2 days)			Shaw AFB (4 days)			Whiteman AFB (2 days)		
	OEL (mg/m3)	# Samples	# > LOQ	Max 8-Hr TWA (mg/m3)	# Samples	# > LOQ	Max 8-Hr TWA (mg/m3)	# Samples	# > LOQ	Max 8-Hr TWA (mg/m3)	# Samples	# > LOQ	Max 8-Hr TWA (mg/m3)	# Samples	# > LOQ	Max 8-Hr TWA (mg/m3)
Copper (fume)*	0.1	8	4	0.038	2	2	0.048	3	3	0.054	13	13	0.108	5	5	0.204
Lead	0.05	8	4	0.092	2	0		3	3	0.005	13	5	0.009	5	4	0.001
Zinc	10	8	0		2	2	0.028	3	3	0.006	13	8	0.012	5	5	0.025
Diphenylamine	10										7	0				
Hydrogen Chloride					1	0		3	0		4	0		5	0	
Hydrogen Cyanide	5.19				2	0		3	0		4	1	0.02	5	0	
Ammonia	17.5				2	0		3	0		4	0		5	0	
Nitric Oxide	30				2	0		3	0		3	0		3	0	
Nitrogen Dioxide	5.6				2	0		3	0		3	0		5	0	
Phosgene	0.4				1	1	0.007	3	0		0	0		5	0	

* Copper Dust OEL is 1 mg/m^3

Between Offutt AFB and Shaw AFB, five firing events were sampled using the cascade impactors. Two of the days resulted in very little copper mass collected. The results from the other three days were averaged and are presented in Figure 1. The majority of copper mass was found to be respirable, less than 4 microns.

Observations of fog released at firing ranges revealed that under certain weather conditions, contaminants may accumulate within the range. Results varied from fog stagnating at shooter’s position to fog being re-circulated back behind the firing line.

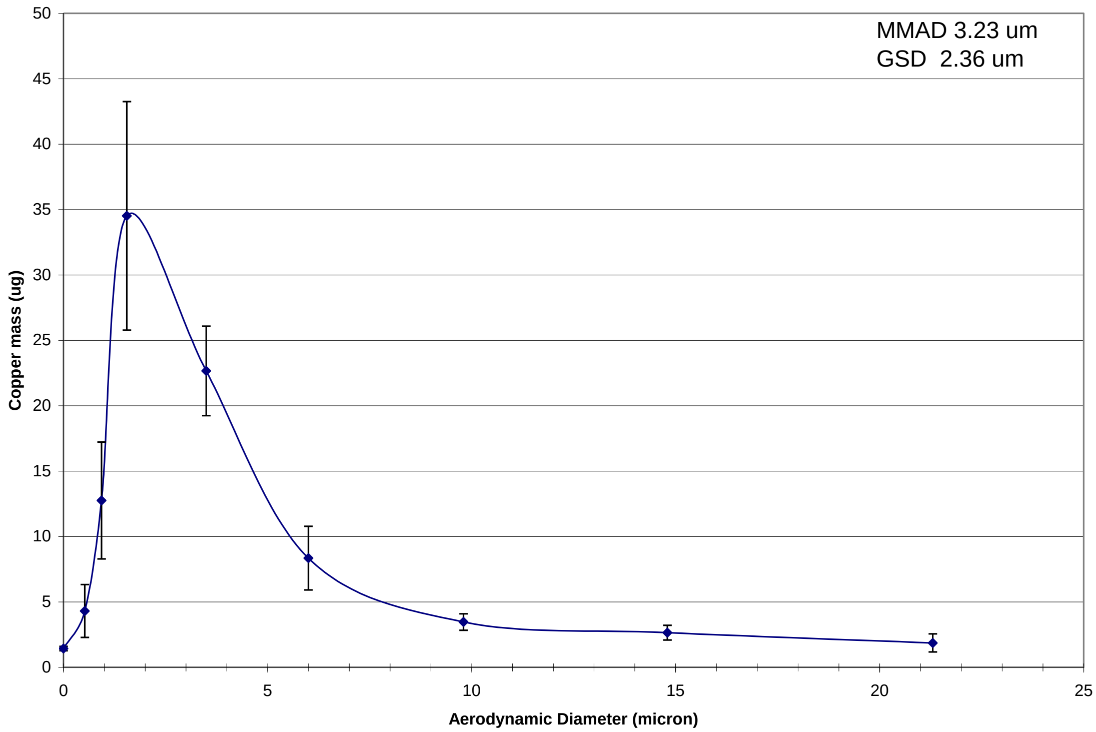

Figure 1. Summary of Copper Particle Size Distribution from Offutt AFB and Shaw AFB

EPIDEMIOLOGICAL QUESTIONNAIRE

Methods

A web-based questionnaire was developed to collect standardized information from ACC CATM instructors. The questionnaire was distributed to all ACC CATM instructors in March 2006. The questionnaire was designed to capture information regarding CATM work practices, symptom data, potential confounders such as allergies, and range structural characteristics. Medical visit data was obtained from the Standard Ambulatory Data Record database to identify potential CATM-related visits and evaluate risk factor associations. Detailed method data can be found in Appendix A.

Each range was assigned a category of "open" or "closed" based on the range structural characteristic data obtained from the questionnaire. Ranges were scored based on the type of walls, roof, back wall and bullet trap. Scores ranged from 0 to 22. Ranges with a score greater than 9 were classified as "closed" and scores 9 and less were classified as "open".

Results

Questionnaires were collected from 101 instructors employed at 18 CATM ranges. 56 out of 101 (55%) surveyed instructors reported adverse health effects from CATM operations. No significant difference in reported symptoms or CATM related clinic visits was noted between instructors firing lead rounds and instructors firing frangible rounds. The risk of experiencing symptoms at bases using frangible bullets was not found to be statistically different from the risk at bases using lead bullets only (OR 1.2 (95% CI 0.5-3.2)). The mean numbers of CATM-related medical visits for instructors exposed to frangible vs. instructors exposed to lead-only bullets were found to be greater for those exposed to frangible but it was not quite statistically significant at the 95% confidence level with a p-value of 0.06 (13.5 and 9.5, respectively). The risk of experiencing symptoms was significantly higher among persons at "Closed" ranges than those stationed at "Open" ranges (OR 3.2 (95% CI 1.3-7.8)). It was also significantly more common for personnel reporting symptoms to have noted seeing visible smoke in the range during firing. Complete results are found in Appendix A.

CHAMBER STUDY

Methods

A Plexiglas chamber, see Figure 2, was designed and constructed to capture the exhaust exiting the barrel of the rifle. Forty rounds of each type of ammunition were fired through the Plexiglas chamber. After forty rounds were discharged, the air within the chamber was sampled for both particulate (metals) and gaseous contaminants. Contaminants were collected and analyzed using standard NIOSH methods. Additionally, Marple 290 personal cascade impactors were used to evaluate the particle size distribution of metal contaminants. Complete method details can be found in appendix B.

Figure 2. Air Sampling Chamber, Pre and Post Firing

Results

TABLE 3. Average Contaminant Chamber Concentration

	Frangible Ammunition (mg/m3)	**Lead Ammunition (mg/m3)**	**Ratio of Frangible to Lead**
Particulate			
Aluminum	2	6	0.3
Antimony	0.4	37	0.01
Barium	4	12	0.3
Calcium	6	11	0.5
Copper	1078	635	1.7
Iron	2	4	0.5
Lead	0.3	317	0.0009
Potassium	71	6	11.8
Sodium	11	20	0.5
Zinc	148	96	1.5
Gases			
Ammonia	1289	857	1.5
Hydrogen Cyanide	3	30	0.1
Nitric Oxide	40	26	1.5

The discharge of lead and frangible rounds generates similar contaminants. Table 3 contains a summary of the results from air sampling the chamber atmosphere. The analysis of particulate matter from the chamber identified several metals, but the primary metals detected were copper, lead and zinc. In addition to the three primary metals, the chamber study identified potassium from frangible rounds and antimony from lead rounds. Analysis of toxic gases only identified ammonia, hydrogen cyanide and nitric oxide. Hydrogen cyanide primarily is associated with exposure from lead rounds. The concentration of the top four shared contaminants is approximately 1.5 times greater in frangible ammunition compared to lead ammunition. Carbon monoxide in the chamber study could not be quantified as the concentration exceeded the range (max of 1000 ppm) of the measuring device. The HAPSITE (portable GC/MS) was used to evaluate the presence of volatile organic compounds during the chamber study. Only trace amounts of benzene (less than 4 ppm) were detected.

Figure 3 shows a comparison of the particle size distribution of copper from lead and frangible ammunition from the chamber study. The amount of respirable copper is comparable from both types of rounds. The mass of copper from 4-10 microns is much greater from frangible rounds compared to the lead rounds.

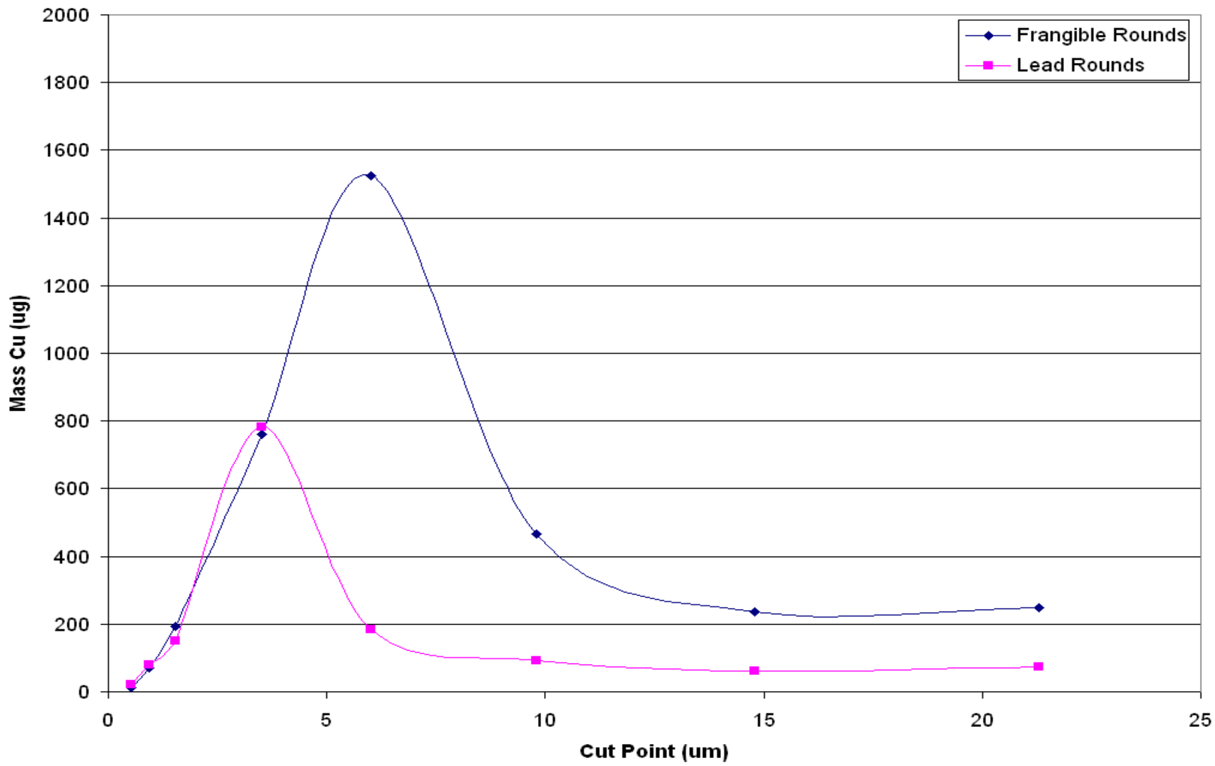

Figure 3. Copper Particle Size Distribution from Lead and Frangible Ammunition

DISCUSSION

Lead vs Frangible

One of the initial concerns communicated by CATM instructors was that frangible ammunition caused adverse health symptoms not experienced from exposures to lead ball ammunition. In general, exposures and health complaints appear similar among the two types of ammunition but that is not unexpected given the similarity of the exposures documented. The epidemiological assessment suggest that the risk of experiencing symptoms while firing lead or frangible rounds was not significantly different, although the study summary cites important limitations in the use of the questionnaire and the data. Results from the chamber study showed similar contaminants were generated from both types of ammunition although the copper size distribution was different and 70% greater in concentration in the frangible exposure.

The chamber results also showed that frangible ammunition generated about 50% more of several contaminants (copper, zinc, ammonia and nitric oxide) than the lead ammunition.

This information tends to support the theory that a threshold concentration exists for one or some of these contaminants above which personnel experience adverse health effects. A 50% increase in these contaminants could explain why ranges previously firing lead did not experience symptoms until switching to frangible ammunition. Ranges with poor ventilation firing lead rounds may experience similar complaints if contaminants accumulate within the range and exceed the threshold concentration. This data does not eliminate the possibility that there are other factors that could cause the complaints related to the frangible munitions.

Exposure Assessment

Characterizing range exposures was more complex than originally anticipated. No single contaminant was identified as consistently exceeding an OEL; yet CATM instructors continue to report adverse health symptoms. This may be due to that fact that sampling at all locations only represented a snapshot in time and conditions could be highly variable due to weather. Copper concentrations at Whiteman AFB and Shaw AFB did exceed 0.1 mg/m^3 (OEL for copper as fume) but not the copper dust OEL of 1 mg/m^3. It was initially assumed that the majority of copper mass was dust but the cascade impactor results show that the majority of copper mass is respirable (more like the size of a fume particle).

The complex mixture of contaminants from unburned propellant and combustion by-products makes it difficult to identify the exact cause of the reported symptoms. Anecdotal data suggests that when the 8-Hr TWA for copper is below 0.1 mg/m^3, personnel do not experience adverse health symptoms. It would be difficult to determine the exact cause of health symptoms, but copper is currently the most likely source and even if it isn't the cause or only cause, it should be representative of the overall exposure. If copper is controlled below a certain concentration, then it is likely the exposure to the whole mixture will be acceptable. Further data is required to determine if there is a dose-response or threshold concentration relationship between exposure and symptoms.

One striking result of the questionnaire was that 55% of the CATM instructors responding had experienced symptoms related to their exposures no matter what ammunition was used. This shows that there is a valid problem with concerns that need to be addressed.

Ventilation systems

The ETL[1] for Small Arms Range Design requires sufficient ventilation to ensure that contaminants are pushed downrange away from the firing line and away from the breathing zone of CATM instructors. The majority of Air Force ranges rely on natural ventilation to accomplish this. Due to safety and environmental concerns, ranges have installed bullet traps, walls, berms etc. which restrict air flow through the range. Natural ventilation is highly variable and being further restricted by the structural design of the range may allow contaminants to accumulate within the range. Smoke tests at ranges studied reveal that under certain weather conditions, contaminants could accumulate within the breathing zone of range personnel. The epidemiological questionnaire found that "closed" ranges are 3.2 times more likely to have personnel experience symptoms versus "open" ranges. Ranges with mechanical ventilation systems may also have problems if the system is not designed properly. Barksdale AFB had mechanical fans installed; yet a lack of laminar flow and a lack of negative pressure down range permitted contaminants to either back flow or be re-circulated back into the area behind the firing line resulting in the lead air concentration exceeding the OEL on one of the days sampled. It is difficult to determine with certainty whether frangible rounds are more likely to cause irritation than lead rounds. There is uncertainty regarding which OEL to use or even if a single OEL can be set that is protective of CATM instructors. What has been observed is that those ranges with previously unacceptable lead exposures are likely to have increased adverse health effects observed when using frangible rounds. In either case, if adequate ventilation is provided, the exposure is significantly reduced and the health effects are eliminated.

RECOMMENDATIONS

Engineering controls (mechanical ventilation)

Ranges should install/upgrade ventilation system to comply with the ETL[1] by ensuring 75 fpm of laminar flow at the shooter's position and slight negative pressure down range. Inadequate airflow will lead to the accumulation of contaminants within the breathing zone of personnel. The best control option is to remove contaminants from personnel's breathing zone using mechanical ventilation. Mechanical ventilation is not likely to be effective if there is much of an opening to the environment so this recommendation essentially advises to either get an indoor range or have a completely open one where no ventilation is needed. A fog generation machine can demonstrate the airflow within a range very effectively if there is a need to test.

The installation or upgrade of a mechanical ventilation system can be costly and time consuming. Interim control measures should be implemented until long term controls can be put in place. Additionally, mechanical ventilation systems may not be feasible or they may be impractical in certain circumstances. Administrative controls and/or personal protective equipment should be considered where ventilation systems cannot be used.

Monitoring and documentation

Base Bioenvironmental Engineering should increase air sampling frequency at firing ranges where there have been complaints or inadequate ventilation is suspected. More sampling data will improve exposure characterization and account for the high variability that may exist. The minimum recommended analytes to sample are metals, respirable dust, total dust, nitric oxide and ammonia. The data gathered at well characterized ranges should be compiled to help the CATM community prioritize which ranges get the limited resources available to upgrade their ventilation systems first.

Ranges should maintain a daily operating log to document range conditions and observations each day shooting is performed. The log should capture class data, weather data, and any health complaints. The log should be used to determine the conditions that occurred when complaints occurred and would ideally be tied into exposure monitoring as well.

Until the relationship between exposure and symptoms is more clearly defined, the use of copper as an indicator of exposure is recommended. Copper levels should be maintained below an 8-Hr TWA of 0.1 mg/m^3. If copper exceeds 0.1 mg/m^3, it is a good indicator that exposures are not adequately controlled and controls should be considered.

Administrative controls

Work practices should be considered as an option to minimize instructor exposure. Class sizes could be reduced to minimize the number of rounds fired at any one time. Worker rotation can be used to reduce the number of days a particular instructor works on the range each week. Weather forecasts can be used to cancel a class on a day expected to produce maximum exposures. Administrative control options should be developed by the instructors themselves and coordinated with Safety, Bioenvironmental Engineering, and others who may be able to address the appropriateness of the measure. The limitations of a particular control option may adversely impact the CATM mission and no one solution may be appropriate for all bases.

Personal protective equipment

Respiratory protection should be considered if engineering and administrative controls are infeasible. Although respirators will protect the worker from inhalation exposure, they may inhibit CATM instructor's ability to communicate with students. Students will also have concerns if instructors receive PPE that they do not have.

CONCLUSION

Health risk assessments at CATM ranges using frangible ammunition can be difficult due to the complex mixture of contaminants generated during the discharge of small arms. OELs have not been sufficient to adequately address health risks of the complex mixture of contaminants as personnel continue to experience adverse health symptoms below what OEL there are available. Given that, a surrogate that is representative of the overall exposure is recommended. The surrogate will be used to determine if exposures are controlled or if controls need to be considered. CATM and BE personnel should coordinate efforts to ensure that any control option allows CATM to accomplish its mission yet protect the health of instructors. Additional data will need to be collected to better characterize range exposures and identify those factors that contribute to the occurrence of adverse health symptoms.

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APPENDIX A EPIDEMIOLOGICAL CONSULTATIVE REPORT

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE FOR OPERATIONAL HEALTH (AFMC)
BROOKS CITY-BASE TEXAS

31 October 2006

MEMORANDUM FOR: AFIOH/RSHI

FROM: AFIOH/RSRH

SUBJECT: Consultative Report, Frangible Bullets Use and Respiratory Symptoms in ACC CATM Range Instructors

1. INTRODUCTION

a. *Purpose*: In February 2005, several Combat Arms Training and Maintenance (CATM) firing ranges within the Air Combat Command (ACC) Major Command changed from using lead bullets to frangible bullets during training sessions due to concerns about lead exposure. Shortly thereafter, instructors employed at these ranges began reporting the occurrence of respiratory and irritation symptoms in conjunction with exposure to the ranges. AFIOH/RSHI was asked by ACC/SGPB to evaluate five of the ranges for particulate levels as well as other environmental dynamics, such as wind, airflow, and building structure. RSHI subsequently requested the assistance of the Epidemiology Services Branch (AFIOH/RSRH) to help determine if adverse symptoms or health outcomes reported by the instructors were related to frangible bullet exposure. RSRH conducted a survey among CATM instructors to investigate whether such a link existed. Also, upon request from ACC/SGPB, RSRH explored the utility of using outpatient data to examine potential relationships between CATM-related exposures and subsequent healthcare visits.

b. *Personnel:*

AFIOH/RSHI:
Lt Col Jonathan Thomas
Maj Jay Vietas
Maj Gary Wright
Capt Michael Moran
Mr. David DeCamp

AFIOH/RSRH:
Maj Renee Shibukawa-Kent
Maj Natalie Johns
Capt Scott Fujimoto

Dr. Jill Feig
Ms. Jill Trei

2. METHODS

a. Internet-Based Survey: RSRH developed a web-based survey tool to collect standardized information from ACC CATM instructors. See Appendix A for a copy of the survey. Question categories included:

(1) Demographics
(2) Potential confounders including allergies, pre-existing medical conditions, medications, smoking, and hobbies involving potential irritants
(3) Exposure time to CATM Ranges
(4) Types and frequencies of weapons used
(5) Symptoms experienced and medical care sought
(6) Questions only for Non-Commissioned Officers in Charge (NCOIC) at each range: structural range characteristics including range construction materials, type of target retrieval system used, range cleaning methods and frequency, ventilation systems, type of bullets used for each weapon involved in training (lead or frangible), and complaints of symptoms from range students
(7) NCOICs were also requested to send photographs of their ranges

Structural characteristics of the ranges were analyzed, both individually and in aggregate, to determine whether factors affecting ventilation may be associated with the occurrence of symptoms. To aggregate the characteristics, range photographs and characteristics described by NCOICs were used by RSHI to rank each range in terms of openness and place it into either an "Open" or "Closed" overall category. NCOIC responses for each range were applied to each instructor responding from that particular range so range characteristics and categories could be analyzed on an individual level.

Potential exposures were compared for persons experiencing symptoms vs. those without symptoms. An instructor was considered "symptomatic" if he/she reported experiencing upper respiratory symptoms listed in the survey, including itchy/watery eyes, sore throat, runny nose, cough, trouble breathing, wheezing, and chest tightness. Attack rates, odds ratios (OR) and 95% confidence intervals were generated using Stata statistical software, version 8.2 to analyze the relationship between symptoms and prior exposures.

b. Outpatient Data Collection and Evaluation: Survey data were joined to medical visit records obtained from the Standard Ambulatory Data Record (SADR) database in order to examine the utility of using medical records data to identify potential CATM-related visits and evaluate risk factor associations.

(1) All outpatient medical visits made by survey respondents between February 2005 and January 2006 were extracted from the SADR database using names and date-of-birth information.

(2) All of the International Classification of Diseases, 9th Revision (ICD-9) codes listed in the extracted visits were reviewed and a condensed list was derived, containing ICD-9 codes considered to represent CATM-related visits. A "potential CATM-related visit" was defined as a visit with an ICD-9 code that was similar to the eye, nose, throat, and other respiratory symptoms that instructors were asked about on the survey. See Appendix B for the ICD-9 codes included on the potential CATM-related visits list.

(3) Relevant visits were retained and compared to survey responses to evaluate accuracy and relevance of using outpatient data to investigate CATM-related illnesses

(a) To examine the correlation between survey responses and SADR data, the proportion of persons reporting symptoms on the survey was compared to the proportion of persons with potential CATM-related visits obtained from SADR. In addition, the proportions of potential CATM-related visits in SADR were compared for those who reported seeking medical care on the survey vs. those who did not. The binomial proportions statistical test was used to compare survey responses to SADR data contents.

(b) To examine the utility of using SADR data to investigate a possible link between frangible bullets use and the occurrence of symptoms, the proportions of persons with CATM-related visits in SADR were compared among ranges using frangible vs. lead-only bullets; Fischer's exact test was used to evaluate this association. In addition, the mean numbers of potential CATM-related visits per instructor over the 12-month timeframe were compared among ranges using frangible vs. lead-only bullets; a group mean t-test was used to evaluate this association.

3. RESULTS: SURVEY

a. Survey data were collected from 101 instructors employed at 18 CATM ranges. Most respondents were male (95 (94.1%)), all were enlisted Air Force personnel, and the mean and median ages of respondents were both 30 years. The CATM NCOIC personnel responded, at least partially, for 17 of the 18 ranges.

b. Among survey respondents, 56 (55.5%) instructors experienced symptoms. The most common symptoms reported were sore/scratchy throat (31 (55.4%)), cough (29 (51.8%)), itchy/watery eyes (23 (41.1%)), runny nose (20 (35.7%)), trouble breathing (15 (26.8%)), and tight chest (12 (21.4%)). Most respondents (45 (80.3%)) reported that symptoms resolved within 3 hours following training.

c. Symptoms occurred among instructors stationed both at ranges using frangible bullets and at those solely using lead bullets. Among the 83 individuals completing a survey for whom information on range bullet use was available, 26 of 46 (56.5%) instructors stationed at ranges using frangible bullets and 19 of 37 (51.4%) instructors stationed at ranges that report only using lead bullets experienced symptoms. The risk of experiencing symptoms at bases using frangible bullets was not found to be statistically different from the risk at bases using lead bullets only (OR 1.2 (95% CI 0.5-3.2*)).*

d. Several structural range characteristics were associated with the occurrence of symptoms. Ranges using bullet traps (OR 3.2 (95% CI 1.1-9.2)) as target retrievals were more associated with symptoms than those using either "berm" or "impact" systems. In addition, ranges with floors made of dirt/sand (OR 0.3 (95% CI 0.1-0.9)) were less associated with symptoms as compared to those with concrete and pea gravel floors. When analyzed by "Open" or "Closed" overall categories, the risk of experiencing symptoms was significantly higher among persons at "Closed" ranges than those stationed at "Open" ranges (OR 3.2 (95% CI 1.3-7.8)).

e. The presence of visible smoke after firing weapons was significantly associated with occurrence of symptoms, and somewhat of a dose-response relationship was observed. Instructors seeing smoke occasionally, most times, and every time after firing were 3.7 (95% CI 0.4-183.7), 20 (95% CI 1.3-1,008.5) and 11.3 (95% CI 1.2-536.1) times, respectively, more likely to experience symptoms than those who never noticed smoke after firing.

f. No potential confounders (allergies, pre-existing conditions, medications, smoking, hobbies) were found to be associated with symptoms.

4. RESULTS: OUTPATIENT CLINIC VISITS

a. No significant correlations were observed between symptoms reported on the survey and medical visits captured in SADR. Potential CATM-related visits were observed in SADR for 27 of 56 (48.2%) of persons reporting symptoms and for 24 of 45 (53.3%) of persons reporting no symptoms on the survey ($p=0.61$).

b. On the survey, only 8 (7.9%) respondents reported seeking medical care for their CATM-related symptoms within the previous 12 months. In contrast, SADR data revealed that 51 (50.5%) of the 101 respondents had one or more potential CATM-related visit during the same time period ($p<0.0001$). In addition, among the 8 persons who reported both experiencing CATM-related symptoms and seeking medical care for those symptoms on the survey, only 5 (62.5%) were identified in SADR using the potential CATM-related ICD-9 code list. Similarly, among the 48 persons who reported experiencing symptoms but not seeking medical care visits on the survey, 22 (45.8%) were identified in SADR as having a potential CATM-related visit ($p=0.38$).

c. Comparing the proportions of potential CATM-related visit(s) in SADR among instructors stationed at ranges using frangible vs. lead-only bullets revealed a non-significant association. Among the 46 instructors stationed at ranges using frangible bullets, 27 (58.7%) had at least one CATM-related visit, while 16 (44.4%) of 36 instructors at bases using lead-only bullets had such visit(s) ($p=0.27$). In addition, the mean numbers of potential CATM-related visits per instructor at ranges using frangible vs. lead-only bullets were found to be statistically similar (13.5 and 9.5, respectively; $p=0.06$).

5. LIMITATIONS

a. Since self-administered surveys were used to collect study data, the accuracy of the data may be compromised. Self-reported answers may be inaccurate due to recall errors or bias.

b. Survey answers provided by NCOICs were sometimes inconsistent, and we did not receive photographs of all ranges. As a result, range features were difficult to characterize in a meaningful way, and the four overall categories generated by RSRH (Completely Open, Partially Open, Mostly Closed, Completely Closed) may not have properly characterized the ranges in terms of exposures.

c. The small size of the study sample limited the ability to evaluate associations between exposures and occurrence of symptoms. For example, only one range could be placed into the Completely Closed category, making it difficult to evaluate whether that type of range was associated with symptoms. Small cell sizes also limited the reliability of some statistical analyses.

d. The large number of exposure variables tested meant that risk factors found to be significant may have been so by chance rather than due to a true association. For example, instructors at Partially Open ranges, but not those at Mostly or Completely Closed ranges, were more likely to report symptoms. Counterintuitive findings such as this may or may not represent true associations and should be explored further.

6. CONCLUSIONS

a. Frangible bullets use, as compared to lead bullets use, was not found to be associated with the occurrence of symptoms.

b. Several structural aspects of the firing ranges appear to be associated with the occurrence of symptoms, including overall openness of the range, target retrieval systems, and material used to construct the range floor. In addition, the association between instructors noticing smoke after firing and the occurrence of symptoms may point to inadequate ventilation as a possible contributor to the problem. These characteristics should be correlated with bioenvironmental measurement data; if relationships exist, the data could be used to provide suggestions on range structure modification to help prevent symptoms from occurring.

c. In this study, using SADR data to identify persons with CATM-related visits and to investigate the link to frangible bullets use was found to be inadvisable for the following reasons:

(1) The large discrepancies observed between symptoms and medical visits reported on the survey and those uncovered using SADR data indicate that searching SADR for relevant visits may not be an accurate way to investigate links between occupational exposures and resulting illness. The fact that the proportions of persons with potential CATM-related visits in SADR were found to be statistically similar among persons who reported symptoms vs. no symptoms, and among persons who reported seeking medical care vs. those who did not on the survey, indicates that SADR may not be reliable source of such data.

(2) Using SADR data to identify persons with occupationally-related symptoms may create more work for investigators than would be needed to conduct a survey among a population of concern. Because the symptom codes used in this study to identify potential CATM-related visits were very general and SADR records do not include reasons for medical visits (e.g. occupational or other), it is likely that at least some of these visits were unrelated to CATM exposures. For example, of the 67 "CATM-related" visits identified in SADR for which symptoms might also suggest an influenza-like illness (cough, sore throat, upper and lower respiratory illness), twenty (29.9%) occurred during the months (December through February) in which influenza activity typically peaks in the Northern Hemisphere; such visits may have been related to viral infections rather than CATM exposures.

(3) Using a survey to collect exposure data, rather than relying on data collected for other purposes, allows investigators to examine associations between specific risk factors and outcomes. In this study, using a survey permitted risk factors such as individual weapons exposure, time on CATM station, and potential confounders to be evaluated against the occurrence of symptoms.

(4) Persons experiencing milder symptoms are less likely to seek medical care and would not be included in SADR. These persons may be more likely captured using a survey.

7. RECOMMENDATIONS

a. The small sample size in this study did not allow for accurate investigation of the true association between exposures and upper respiratory symptoms. To better characterize the association, an expanded version of this study should be conducted with a larger sample size.

b. Results from the environmental testing already performed by RSHI at several ACC CATM ranges should be evaluated within the context of RSRH results to further investigate a potential link between frangible bullets use, environmental characteristics of CATM ranges, and presence of symptoms. Final recommendations on range modification should include the environmental findings.

c. The value of using SADR data to examine associations between occupational exposures and mild health outcomes is limited, due to the lack of correlation to survey data in this study, the non-specific nature of certain disease and symptom codes, the lack of supplemental coding for occupational exposures, and the potential for missing cases who did not seek medical care. Until occupational or environmental exposures are more integrated in medical databases, customized surveys remain the best way to link symptoms with exposure history.

8. Please direct any additional questions or concerns to Maj Natalie Johns at DSN 240-3471.

//SIGNED//

NATALIE M. JOHNS, Maj, USAF, BSC
Public Health Consultant, AFIOH/RSRH

APPENDIX B EPIDEMIOLOGICAL QUESTIONNAIRE

GENERAL SURVEY: ALL PARTICIPANTS

Last Name: Date Survey Completed:
First Name: Age: Rank:
Sex : M / F Base:

Do you have seasonal, pet, or environmental allergies? (e.g. “hay fever”) Y / N
If YES, how many years: (please check one) <5 yrs, 5-10 yrs, 10+ yrs
If YES, do you take medications as prescribed or recommended on the package for the allergies? Y / N
If YES, does the medication completely or almost completely control your allergy symptoms? Y / N

Do you have any of the following medical conditions (check all that apply)?
Asthma Sinusitis __Heart disease _____Emphysema
Sleep related breathing disorder (Apnea)_____ Chronic Bronchitis________
High blood pressure_____ “Dry eye” or other eye condition_____ Other ________

If “Other”, please list:______________

Do you take any prescription or over-the-counter medicines? Y / N
If YES, please list medicines here: ______________________________________

Do you smoke? Y / N
If YES, how many years?: (please check one) less than 1, 1-5 yrs, 6-10, >10
If YES, how many packs per day?: (please check one) less than 1 pack, 1 pack, 2 packs, 3 packs or more

What off-duty work or hobbies you do (check all that apply)?:
Gardening Home Repairs Furniture refinishing
Painting/Varnishing Car Repairs Carpentry/woodworking None
Other: ____

When did you begin assignment as a CATM trainer?
Year: (drop down: before 1985, 1985, 1986… 2005)
Month: (drop down)

When did you first arrive at present base location?
Year: (drop down: before 1995, 1995, 1996…2005)
Month:(drop down)

On average, how many days do you give CATM training for the following weapons:
M-9? Days per week: (drop down 0-7)
M-4? Days per week: (drop down 0-7)
M-16? Days per week: (drop down 0-7)
M-240/249? Days per **MONTH**: (drop down 0 – 31)
Other: (free text box)

On average, how many hours per day do you do CATM training for the following weapons?
M-9? Hours: (drop down 0- 12 for all of these)
M-4? Hours:
M-16? Hours:
M-240/249? Hours:
Other? Hours:

Do you notice smoke from firing while at training? (please check one)
Never Occasionally About Half the Time Most/All of the Time

Do you have any symptoms during or immediately following training (occur within 30 minutes of ending training)? Y / N
If NO – skip to "Are you the NCOIC for CATM?" (last question below)
If YES – continue with following questions

Please check any of the symptoms you have (check all that apply):

Itchy / Watery Eyes	Trouble Breathing
Runny Nose	Chest Tightness
Sore/Scratchy Throat	Wheezing
Cough	Other: ____________________________________

How often do the symptoms occur during training? (please check one)
Every Time Most of the Time About Half the Time Occasionally

How long do the symptoms last? (please check one)
Only during training <30minutes 31 min – 59 min 1-3hrs
>3hrs but less than 1 day Doesn't resolve

Do you have these symptoms on your days off? Y / N

How does the wind affect symptoms? (please check one)
Worse during windy days Better during windy days No effect Not sure

Do you notice symptoms occur more frequently with a particular weapon or weapons?
Y / N
If YES, which weapon(s)? (check all that apply)

M9	M16	Other
M4	M240/249	

Do you take any cold or allergy medications specifically to suppress these symptoms you experience during or immediately following training? (please check one)

Every day	Most days	Occasionally	Never

Please check the months in which you've had symptoms (check all that apply):

Before Feb 05	February 2005	June	October
March	July	November	
April	August	December	
May	September	January 2006	

Did you seek medical care at any time for your symptoms? Yes / No
If YES, in what month(s) (check all that apply)?

February 2005	June	October
March	July	November
April	August	December
May	September	January 2006

Are you the NCOIC for CATM? Yes / No
If YES, proceed to NCOIC survey; if NO, end of survey

QUESTIONS FOR RANGE NCOIC ONLY

Administrative Information:	
Current shop roster	
Name	SSN (no dashes)
1-	
2-	
3-	
4-	
5-	
6-	
7-	
8-	

9-

10-

11-

12-

Process Information:

General Base Training

Weapon Type (check all that apply)

M16 Clear

1. Use Frangible Bullets
2. If yes, Year/Month began using frangible bullets

   Year: Month:

3. Average # students per class (not firing positions)
4. # rounds fired per student per class

M9 Clear

1. Use Frangible Bullets
2. If yes, Year/Month began using frangible bullets

   Year: Month:

3. Average Average # students per class (not firing positions)
4. # rounds fired per student per class

Other Weapons Clear

1. Use Frangible Bullets
2. If yes, Year/Month began using frangible bullets

   Year: Month:

3. Average Average # students per class (not firing positions)
4. # rounds fired per student per class

Security Forces Training

Weapon Type (check all that apply)

M4 Clear

1. Use Frangible Bullets

2. If yes, Year/Month began using frangible bullets

Year: Month:

3. Average # students per class (not firing positions)

4. # rounds fired per student per class

M16 Clear

1. Use Frangible Bullets
2. If yes, Year/Month began using frangible bullets

Year: Month:

3. Average # students per class (not firing positions)

4. # rounds fired per student per class

M9 Clear

1. Use Frangible Bullets
2. If yes, Year/Month began using frangible bullets

Year: Month:

3. Average # students per class (not firing positions)

4. # rounds fired per student per class

M240/249 Clear

1. Use Frangible Bullets
2. If yes, Year/Month began using frangible bullets

Year: Month:

3. Average # students per class (not firing positions)

4. # rounds fired per student per class

Other Weapons Clear

1. Use Frangible Bullets
2. If yes, Year/Month began using frangible bullets

Year: Month:

3. Average Average # students per class (not firing positions)

4. # rounds fired per student per class

Range Characteristics

1. How many shooting positions are located on your range?	
2. Describe each component of the CATM range	
a. Behind the Target	Other:
b. Sidewall	Other:
c. Floor	Other:
d. Range Roof Type	Other:
e. Range Roof Material	Other:
f. Firing Line Roof	Other:
g. Behind Shooter	Please Describe:(If possible please send picture(s) (view/hide recommended angle of picture) to: episervices@brooks.af.mil please use Subject Line:CATM Survey response ID-15052006/09:42:36. Please be specific: Examples include *"brick wall with 7 garage doors, 2 windows, additional door for personnel entry"* or *"cement wall, 4 windows that open and 2 doors"* or *"no wall"*) 200 characters left

3. Target Retrieval system	
4. Clean up Operations	
a. How does range cleaning occur	Other:
b. Frequency of cleaning	Other:
c. Who performs cleaning	Other:
Ventilation System	Other:
Health Effects of Students	
- a. Do students complain of irritation after firing at your range?	
- b. If **Yes**, does it occur more often after a certain type of class? (Check all that apply)	M9 Clear M16 Clear M4 Clear M240/249 Clear No Clear Other weapon(s):
Reset	

SADR ICD-9 codes associated with potential CATM-related outpatient visits for survey participants

Condition	ICD-9 Code
Other specified visual disturbances	368.8
Disorders of conjunctiva	372
Other chronic allergic conjunctivitis	372.14
Blepharoconjunctivitis	372.2
Other and unspecified conjunctivitis	372.3
Conjunctival edema	372.73
Other scleritis and episcleritis	379.09
Acute nasopharyngitis	460
Acute sinusitis	461
Acute sinusitis, unspecified	461.9
Acute pharyngitis	462
Acute upper respiratory infection, unspecified site	465.9
Acute bronchitis/bronchiolitis	466
Chronic sinusitis, unspecified	473.9
Allergic rhinitis	477
Other allergic rhinitis	477.8
Allergic rhinitis, unspecified	477.9
Other upper respiratory disease	478
Other diseases of nasal cavity and sinuses	478.1
Bronchitis, unspecified	490
Asthma, unspecified	493.9
Asthma, unspecified	493.90
Other disease of trachea and bronchus, not elsewhere classified	519.1
Symptoms involving head and neck	784
Throat pain	784.1
Other symptoms involving head and neck	784.9
Shortness of breath	786.05
Wheezing	786.07
Other symptoms involving respiratory system and other chest symptoms	786.09
Cough	786.2
Painful respiration	786.52
Superficial injury of cornea	918.1
Other eye problems	V41.1
Special screening for other eye conditions	V80.2

APPENDIX C CHAMBER STUDY

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE FOR OPERATIONAL HEALTH (AFMC)
BROOKS CITY-BASE TEXAS

11 Apr 07

MEMORANDUM FOR RECORD

SUBJECT: In-house Report, Air Sampling in a Chamber at an Outdoor Firing Range during Use of Lead and Frangible Bullets Part 2, Lackland AFB TX

1. INTRODUCTION

a. *Purpose*: On 5 Feb 07 and 13 Mar 07, the Industrial Hygiene (IH) Branch of the Air Force Institute for Operational Health (AFIOH/RSHI) conducted an assessment of hazardous materials generated during the firing of lead and frangible 5.56 mm ammunition (Olin Winchester M193 and Federal Cartridge Company respectively). Although lead rounds are still used in the Air Force when firing large caliber weapons, the use of frangible ammunition is beginning to be widely used with the smaller caliber weapons. The primary purpose of this study was to identify potential differences in the firing of lead and frangible ammunition that may aid in performing health risk assessments.

b. *Survey Personnel*:

Capt Michael Moran, Senior Industrial Hygiene Consultant
SSgt Jerimiah Jackson, Industrial Hygiene Technician
SrA Sondra Tucker, Industrial Hygiene Technician

c. *Personnel Contacted*:

MSgt Norman Watson, 342 TRS/SFTB
SSgt Todd Vidic, 342 TRS/SFTB

d. *Equipment Used*:

SKC High-Flow Air Sampling Pumps
Marple Personal Cascade Impactors (8-stage)
BIOS International Dry Cal Calibrator, (Serial Number DC-L 1583)
INFICON HAPSITE®

2. SURVEY CONDITIONS: The survey was conducted at an outdoor range. The area behind the firing line had concrete floors and an overhead protective covering. There was little to no wind on both days.

3. SURVEY PROCEDURES

a. Lead and frangible rounds were fired through a Plexiglas chamber using the M-4 rifle. The chamber was designed to allow the bullet to pass through the chamber while gases from the muzzle were captured within the chamber (Figure X). Frangible bullets were fired on 5 Feb 07 and lead bullets were fired on 13 Mar 07. Four consecutive firings were conducted. The first two firings were sampled for particulates using 37 mm cassette and cascade impactor and the last two firings were sampled for toxic gases using sorbent tubes. During each firing, 40 rounds were fired in rapid single shot succession. Each firing or sampling event was initially set at 20 minutes but was reduced to 10 minutes (5 minutes for 37 mm cassettes) to prevent overloading sample media. Sample pumps were turned on after firing all 40 rounds. The hoses from the SKC air sampling pumps were fed through small openings on the side of the chamber and 0.7 liter tedlar bags were filled from a small opening on the side of the chamber for later analysis with the HAPSITE®.

b. The media and collection methods are identified in Table 1. Current methods from the National Institute for Occupational Safety and Health (NIOSH) and Occupational Safety and Health Administration (OSHA).

TABLE 1. Media and Collection Methods

Sampling Method	Sample Media	Flow rate	Analytes collected
NIOSH Method 7300	37 mm cassette with 0.8 μm cellulose ester membrane, and 34 mm 5.0 μm MCE	2.0 Liter/min	Metals
NIOSH Method 7903	Silica gel sorbent tube (SKC 226-10-03)	0.3 Liter/min	Hydrogen chloride
NIOSH Method S347	Silica gel sorbent tube (SKC 226-10-06)	0.2 Liter/min	Ammonia
NIOSH Method 6014	Molecular sieve sorbent tubes (SKC 226-40)	0.025 Liter/min	Nitric oxide, nitrogen dioxide
NIOSH 2507	Tenax sorbent tube (SKC 226-35-03)	1.0 Liter/min	Nitroglycerin
NIOSH 6010	Solid sorbent tube (SKC 226-28)	0.2 Liter/min	Hydrogen Cyanide
OSHA Method 78	37 mm cassette with preloaded coated filters (SKC 225-9004)	1.0 Liter/min	Diphenylamine
HAPSITE GC/MS	0.7 L Tedlar Bag	Grab Sample	Volatile Organics

Air Sampling Chamber, Pre and Post Firing

4. RESULTS

a. All results for contaminants detected above the level of detection are summarized in Table 2. Cascade impactor results indicate that the majority of particulate matter has an aerodynamic diameter less than 6 microns. Cascade impactor copper results are summarized in attachment 1.

TABLE 2. Average Contaminant Concentration

	Frangible Ammunition (mg/m3)	Lead Ammunition (mg/m3)
Particulate		
Aluminum	2	6
Antimony	0.4	37
Barium	4	12
Calcium	6	11
Copper	1078	635
Iron	2	4
Lead	0.3	317
Potassium	71	6
Sodium	11	20
Zinc	148	96
Gases		
Ammonia	1289	857
Hydrogen Cyanide	3	30
Nitric Oxide	40	26

b. In addition to the above analysis that was sent to a laboratory for analysis, 0.7 L tedlar bags were analyzed in-house with the HAPSITE® using the 15 minute sample loop method. Benzene was detected in both lead and frangible samples. Concentrations were estimated to be less than 4 ppm.

5. DISCUSSION

a. The previous chamber test failed to capture contaminants emitted from the muzzle of the weapon. The chamber was redesigned to allow the bullet to pass through the chamber while containing contaminants discharged from the muzzle within the test chamber. The majority of contaminants are discharged from the muzzle, not the ejection port.

b. Based on the concentrations obtained in this study, the primary contaminants of concern are copper, lead, zinc, ammonia, nitric oxide and hydrogen cyanide. Additionally, potassium for frangible rounds and antimony for lead rounds may be of interest.

c. Outside of trace levels of benzene, no volatile organic compounds were detected using the HAPSITE.

d. Carbon monoxide concentrations exceeded the upper limit of the meter and could not be quantified.

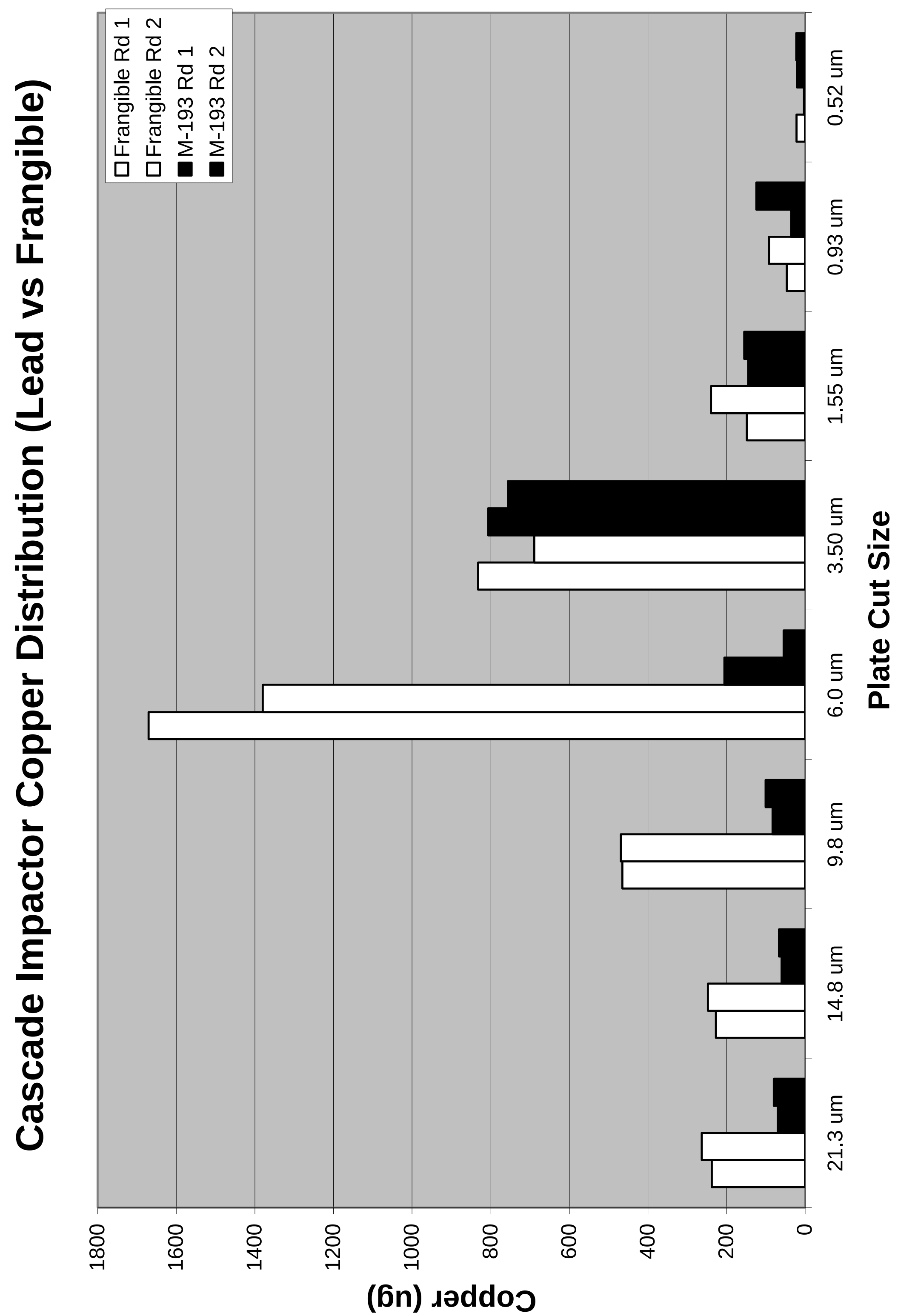
e. There are only minor differences in contaminants generated while firing lead or frangible rounds. Initial findings support the idea that smoke from any type of ammunition will cause symptoms reported by CATM instructors. There doesn't seem to be any unique differences that would indicate a specific contaminant in the smoke from frangible ammunition is responsible for the reported symptoms.

f. Cascade impactor data revealed that the majority of metal particulate has a mean aerodynamic diameter of less than 6 microns for both lead and frangible ammunition.

g. Visual observations indicate a greater accumulation of particulate in the chamber for frangible rounds compared to the lead rounds. This is consistent with reports from CATM instructors of an increased frequency to clean the range.

//SIGNED//
MICHAEL P MORAN, Capt, USAF, BSC
Senior Industrial Hygiene Consultant

Attachment:
Cascade Impactor Copper Distribution (Lead vs Frangible)



Cascade Impactor Copper Distribution (Lead vs Frangible)
Copper (ug)
0
200
400
600
800
1000
1200
1400
1600
1800
Plate Cut Size
21.3 um
14.8 um
9.8 um
6.0 um
3.50 um
1.55 um
0.93 um
0.52 um
Frangible Rd 1
Frangible Rd 2
M-193 Rd 1
M-193 Rd 2

APPENDIX D AREA MONITORING RESULTS

		Barksdale AFB (2 days)			Ellsworth AFB (1 day)			Offutt AFB (2 days)			Shaw AFB (4 days)			Whiteman AFB (2 days)		
	OEL (mg/m3)	# Samples	# > LOD	Max 8-Hr TWA (mg/m3)	# Samples	# > LOD	Max 8-Hr TWA (mg/m3)	# Samples	# > LOD	Max 8-Hr TWA (mg/m3)	# Samples	# > LOD	Max 8-Hr TWA (mg/m3)	# Samples	# > LOD	Max 8-Hr TWA (mg/m3)
Copper (fume)*	0.1	6	2	0.04				1	1	0.095	13	13	0.112	1	1	0.113
Lead	0.05	6	4	0.056				1	1	0.025	13	4	0.003	1	1	0.001
Zinc	10	6	0					1	1	0.011	13	9	0.013	1	1	0.015
Diphenylamine	10										13	0				
Hydrogen Chloride								1	0		8	0		1	0	
Hydrogen Cyanide	5.19							1	0		8	3	0.067	1	0	
Ammonia	17.5							1	0		8	1	0.183	1	0	
Nitric Oxide	30							1	0		6	0				
Nitrogen Dioxide	5.6							1	0		6	0				
Phosgene	0.4							1	0		2	0				
Phenol	19.2										3	0				

* Copper Dust OEL is 1 mg/m^3

APPENDIX E FRANGIBLE BULLET MSDS

MATERIAL SAFETY DATA SHEET

SMALL ARMS AMMUNITION
BALLISTICLEAN 5.56MM
CENTERFIRE RIFLE AMMUNITION

Federal Cartridge Company
900 Ehlen Drive
Anoka, Minnesota 55303

TELEPHONE: 763-323-2300
PRODUCT SERVICE: 763-323-3706
EMERGENCY PHONE NUMBER: 800-424-9300 (CHEMTREC)

Issue Date: August 19, 2003

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SECTION #1 - PRODUCT IDENTIFICATION:

NON-TOXIC CENTERFIRE RIFLE PRODUCT FAMILY		
Centerfire Metallic Cartridge Including The Following:		
BC556NT1		

SECTION #2 - CHEMICAL COMPOUNDS:

CHEMICAL COMPOUNDS			
		TWA UNLESS OTHERWISE NOTED	
	CAS NUMBER	OSHA PEL	ACGIH TLV
Bullet *Copper Jacket	7440-50-8	1 mg/m^3 Fume: .1 mg/m^3	1 mg/m^3 Fume: .2 mg/m^3
Core: Copper Powder (See Above)			
Zytel Nylon	None Assigned	15 mg/m^3 (5 mg/m^3 as respirable dust)	15 mg/m^3 (5 mg/m^3 as respirable dust)
Cartridge Case – Brass (As Copper) (See above)			
* Zinc (As Zinc Oxide)	7440-66-6 1314-13-2	10 mg/m^3 (5 mg/m^3 as respirable dust) Fume: 5 mg/m^3	10 mg/m^3 Fume: 5 mg/m^3
Propellant – Nitrocellulose	9004-70-0	Not Established	Not Established
*Nitroglycerine	55-63-0	.1 mg/m^3 STEL	.46 mg/m^3 (Skin)
Diphenylamine	122-39-4	Not Established	10 mg/m^3
Primer - Diazodinitrophenol	87-31-0	Not Established	Not Established
Tetracene	109-27-3	Not Established	Not Established
* Barium Nitrate (As Barium)	7440-39-3	.5 mg/m^3	.5 mg/m^3
*Aluminum	7429-90-5	15 mg/m^3 (5 mg/m^3 as respirable dust)	10 mg/m^3
Nitrocellulose (See above)			
Nitroglycerine (See above)			

* Indicates toxic chemical(s) subject to the reporting requirements of section 313 of title III of the Superfund Amendments and Reauthorization Act (SARA) of 1986 and 40 CFR 372.

DEFINITIONS OF ACRONYMS

OSHA PEL: Occupational Safety and Health Administration's Permissible Exposure Limit.

ACGIH TLV: American Conference of Governmental Industrial Hygienists' Threshold Limit Values.

TWA: Time Weighted Average.

STEL: Short Term Exposure Limit, the 15-minute exposure that should not be exceeded at any time during a workday.

CEILING: The concentration that is not to be exceeded at any time during a workday.

CAS: Chemical Abstracts Service number.

SECTION #3 - PHYSICAL DATA

Boiling Point:	Not Applicable
Melting Point:	Not Applicable
Vapor Pressure:	Not Applicable
Density:	3.1 - 8.0 grams/cc
Solubility (Water):	None
Evaporation Rate:	Not Applicable
Percent Volatiles:	Not Applicable
Vapor Density (Air = 1):	Not Applicable
Appearance:	Brass case with copper/Zytel nylon bullet.
Odor:	None
Odor Threshold:	None

SECTION #4 - FIRE FIGHTING & EXPLOSION DATA:

Flash Point (F):	Not Applicable
Auto Ignition Temperature (F):	Not Applicable
Upper Explosive Limits (Percent):	Not Applicable
Lower Explosive Limits (Percent):	Not Applicable

Fire & Explosion Hazards: May ignite if heated to 250 degrees F, independent of air. Unconfined ignited cartridges can produce low velocity metallic fragments that may cause eye injury or superficial skin wounds if unprotected by standard fire-fighter turnout gear.

Extinguishing Media: Water

Special Fire Fighting Instructions: Wear full fire-fighter protective gear including face shield or SCBA. Use wide fog pattern nozzle to stop any low velocity fragments. Use water to cool ordinary combustibles below ignition temperature.

SECTION #5A - EXPOSURE & EFFECTS -- INHALATION

ROUTE OF EXPOSURE & EFFECTS - INHALATION

Acute: Acute inhalation of smoke may produce mild throat and eye irritations.

Chronic: None known.

First Aid: Remove person to fresh air. If breathing has stopped, administer artificial respiration. If symptoms should appear, contact physician.

SECTION #5B - EXPOSURE & EFFECTS -- SKIN

ROUTES OF EXPOSURE & EFFECTS - SKIN

Acute: Contact with metal fumes may cause skin irritation.

Chronic: None known.

First Aid: Wash thoroughly with soap and water.

SECTION #5C - EXPOSURE & EFFECTS -- EYES

ROUTES OF EXPOSURE & EFFECTS - EYES

Acute: Contact with large volumes of smoke may cause minor eye irritation.

Chronic: None known.

First Aid: Remove person to fresh air. If foreign body is suspected, wash eyes in fresh water for 15 minutes, contact physician.

SECTION #5D - EXPOSURE & EFFECTS -- INGESTION

ROUTE OF EXPOSURE & EFFECTS - INGESTION

Acute: Ingestion of nitroglycerin is known to cause headaches, convulsions, tachycardia and apnea. Ingestion is not a likely route of exposure.

Chronic: None known.

Note: Wash hands thoroughly with soap and water before eating or smoking.

First Aid: Ingestion is not a likely route of exposure. In case of ingestion, contact physician.

SECTION #5E - EXPOSURE & EFFECTS -- CARCINOGENESIS DATA

N.T.P.: No

I.A.R.C.: No

OSHA: No

SECTION #5F – EXPOSURE & EFFECTS – COMMENTS

Barium is a toxic metal, at high concentrations. Ballisticlean ammunition contains trace levels of Barium.

SECTION #5G - AGGRAVATION OF PRE-EXISTING HEALTH CONDITIONS

AGGRAVATION TO PRE-EXISTING HEALTH CONDITIONS

None known.

SECTION #6 - REACTIVITY & POLYMERIZATION

Stability: Stable under normal use conditions.

Conditions to Avoid: Individual cartridges may ignite if the primer is struck or if the cartridge is exposed to excess heat.

Incompatible Materials: Oils, Acids, Alkalies, Ammonia, and other corrosive materials.

Hazardous Decomposition Materials: Oxides of Barium, Nitrogen and Carbon.

Polymerization: Will not occur.

SECTION #7 - SPILLS, LEAKS & DISPOSAL PROCEDURES

STEPS TO BE TAKEN - SPILLS:

Avoid conditions detailed in Section #6. If container should rupture place all loose cartridges from broken shipping cases into a sturdy container, secure container carefully.

Waste Disposal Methods: Contact Manufacturer - Product Service (763) 323-3706.

SECTION #8 - SPECIAL PROTECTIVE EQUIPMENT

Ventilation: Use in a well-ventilated area. Consult the current edition of ACGIH Industrial Ventilation Manual and/or NRA ventilation recommendations.

Protective Equipment:

Eyes: Recommend protective eyewear conforming to ANSI Z-87.

Gloves: Not generally required.

Respirators: Use an approved respirator while cleaning range facilities if applicable exposure limits are exceeded.

Hearing Protection: Hearing protection recommended while discharging cartridges.

SECTION #9 - SPECIAL PRECAUTIONS -- STORAGE & HANDLING

Store in a dry, cool area in the original container to assure performance. Keep out of the reach of children. Avoid striking the primer of unchambered cartridges. Remove ammunition from service if any of the following conditions have occurred:

1. Prolonged storage at or above 170 degrees F.
2. Evidence of corrosion.
3. Physical damage.
4. Exposure to oil or spray type lubricants.

Avoid prolonged storage in leather cartridge carriers. Cartridges can ignite if heated to 250 degrees F independent of air.

SECTION #10 – TRANSPORTATION INFORMATION

This material is a US Department of Transportation Hazardous Material.

US DOT Proper Shipping Name:	Cartridges, small arms
Hazard Classification:	1.4S
UN Identification Number:	UN0012
Packing Group:	II

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